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MANGROVE SOILS, SPECIES RELATIONSHIPS AND ECOSYSTEM MANAGEMENT

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INTRODUCTION

The word mangrove is a combination of Portuguese and English. It is derived from the Portuguese word for an individual mangrove tree, *mangue*, and from *grove*, the English word for a group or stand of trees. The term mangroves generally apply to an association of trees which are found in wet, loose soils in tropical tide waters. The different groups of plants that are defined as mangroves have been categorized as true mangroves and as mangrove associates or *associes.* Although mangroves are trees, yet their form is very versatile: most of them occur as low, scrubby plants in harsh conditions; but their canopies can reach heights of over 40 meters where conditions are favorable. However, when referring to the mangrove habitat, the terms mangroves or *mangal* are used (Macnae 1968). The habitat that includes trees, shrubs, palms, epiphytes and ferns can also be referred to as mangrove forest or sometimes as tidal forest. Mangroves are best developed in extent and variety of trees when bordering the coastal margins of the tropical rainforest, although several occurrences have been reported in the higher latitudes One of the most important mangrove habitats in the world occur in the River Niger Delta in Nigeria, to the east the Cross River Estuary in Nigeria and Cameroon, around Doula in Cameroon, and the Muni Estuary and Como River in Gabon. The delta mangroves mark the transition between swamp forest habitats to pioneer communities on the coast and can achieve a width of over 45 km wide.

Mangrove soils

In mangroves, great difficulty is usually experienced in obtaining deep sub-surface samples with the soil auger. The high water table often limits the sampling depth to about one metre. In most cases, the mangrove soil is almost a soft liquid mass. Most mangrove soils usually show very little profile differentiation up to this depth. As a result of the high water table, holes dug in the marsh could be completely filled with water within a few minutes.

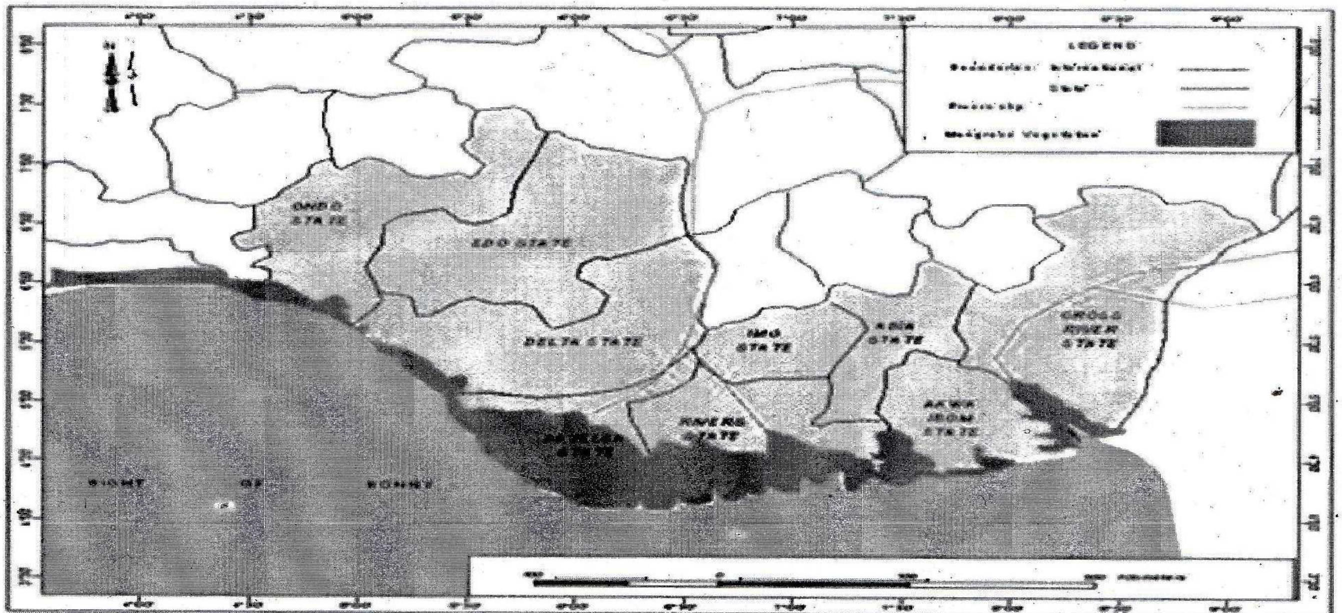

Fig. 1: Mangroves along the shoreline of the River Niger Delta

Therefore pedological descriptions of soil could differ markedly between sites if collection of soil samples is kept to a minimum to avoid disturbance. We used a 'swamp corer' modified after Giglioli and Thornton (1965a) to obtain soil cores for profile descriptions. The corer enables soil cores of up to 1m depth to be obtained from the mangrove swamp.

The mangrove soils could be defined as *halotropic* soils to designate the fact that profile development is related to salt water, brackish water and the effective activity of plant communities (that are associated in a successional trend). The soil could also be classified according to their halomorphic characteristics and degree of salinity. The halomorphic soils could be further classified according to the degree to which they are flooded. In the same area, Giglioli and Thornton (1965b) attempted a classification based on the relative contents of chlorides and sulphates in the soils. These attempts are handicapped because hydromorphic properties of mangrove soils vary, even within the same locality. As a result the schemes lack general application, although they could be suitable for the classification of relatively small areas for specific purposes e.g. subdivisions of the soil on the basis of their agricultural potentials.

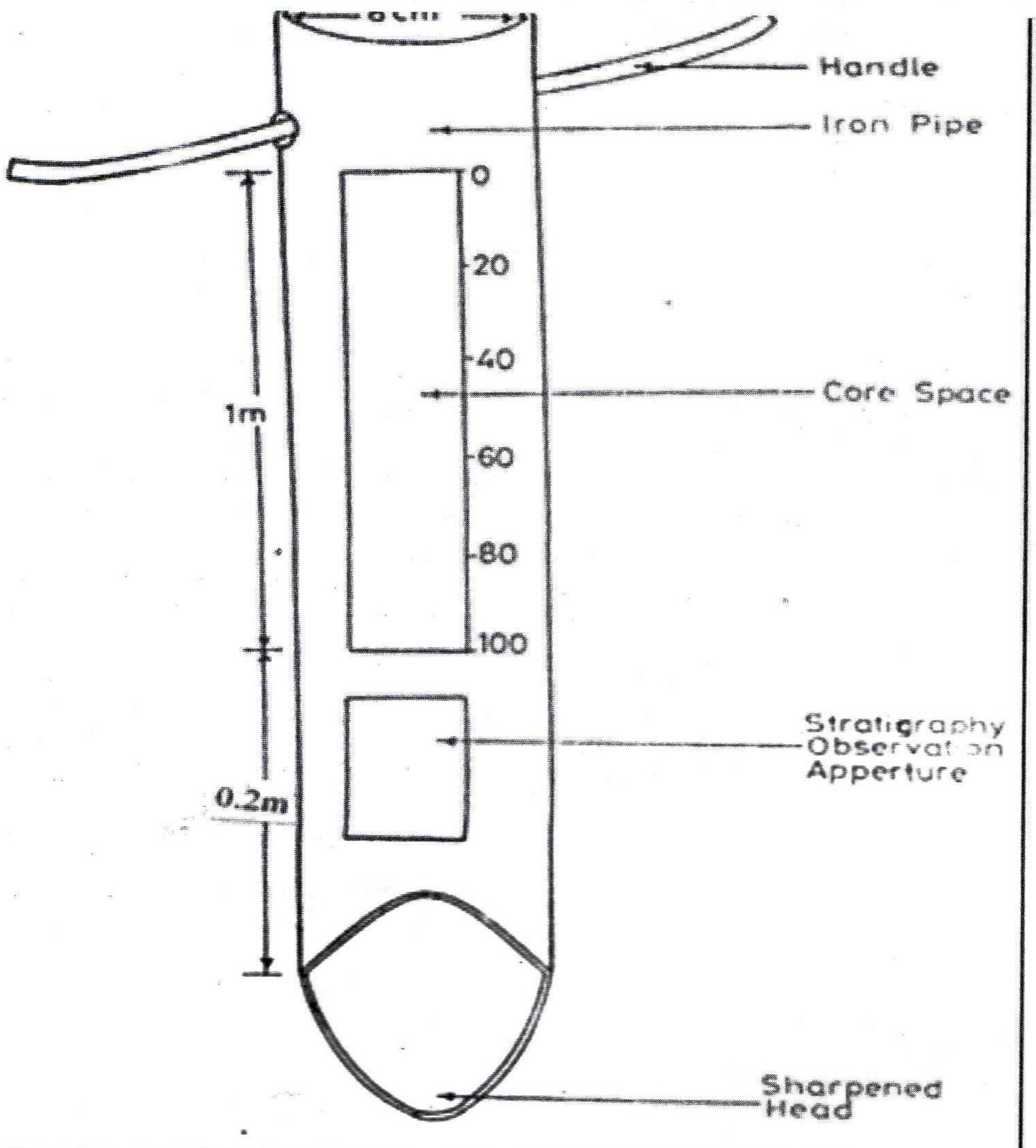

Fig. 2: Diagram of the 'Swamp corer' (not to scale) modified after Giglioli and Thorton (1965a)

According to the system defined for the Soil Map of Africa, soils under Mangrove vegetation are *Juvenile soils* formed on marine alluvium and belong to the order of *weakly developed soils*. The classification holds for soils that are frequently flooded by tide waters. Other soils associated with mangrove which are not frequently flooded belong to the order *Halomorphic soils* since the profiles of their uppermost horizons are differentiated, being usually dry during parts of the year. The differentiated soils are further classified as *saline* and *saline-alkali soils* based on the percentage saturation of the exchange complex with sodium. In the American Soil Taxonomy the soils fit into the order *Entisols* and the sub-order *Aquents* – which are saturated by water at some time of the year.

Table 1: Code for Mangrove soil profile descriptions

Property	Scale	Definition
Root content (Wet)	0-3	0 = No root content 1 = Few root content 2 = Numerous root content 3 = Highly fibrous
Stickiness (wet)	0-3	0 = Not sticky 1 = Not/slightly sticky 2 = slightly sticky 3 = very sticky
Plasticity (wet)	0-3	0 = Not plastic 1 = Not/slightly plastic 2 = Slightly plastic 3 = Very plastic
Structure (wet)	1-4	1 = Massive 2 = Angular 3 = Angular/blocky 4 = Blocky
Hardness (air dry)	1-3	1 = Moderately hard 2 = Hard 3 = Very hard

Mangrove soil profiles

Initial investigation of mangrove soil profiles requires the identification of swamp segments where similar geomorphic and hydraulic processes operate in the nearby water channels. This is because flocculation and deposition of sediments are important in the evolution of mangrove soils. The mangrove soils in the estuaries of the Creek Town Creek/Calabar River, Kwa Iboe River and Imo River which are extensions of the Niger Delta Mangroves have been used as examples in this investigation. Table 1 shows the code that was used for the profile descriptions. Tables 2-10 show soil profile descriptions and the corresponding particle size composition from the varying segments of the swamps.

Table 2: Soil profile* description of the Creeks Town Creek/CalabarRiver Mangrove swamp in South eastern Nigeria

	(a)Creek Town Segment		(b)Calabar River Segment	
Horizon	Surface	Subsurface	Surface	Subsurface
Colour (Munsell)	Very dark Grayish brown (2.5Y3/2 - 2.5Y4/2)	Very dark grey (5Y3/1): Black (7Y2.5/2).	Very dark Grey (5Y3/1)	Very dark Grey (2.5YN3/0) – Black (2Y2.5/1).
Mottles (Munsell)	Yellowish Brown(10YR5/8)	Reddish Yellow(7.5YR7/8)	-	Strong brown (7.5YR4/2)
Root content	1, 2, 3	0, 1	1	0
Stickiness	2	3	1	2
Plasticity	2	2	2	2
Structure	1, 2, 3	1, 2, 3	3	3
Hardness	2	2	3	3

*minimum of 5 observations

The soils of both segments of the swamp shown in Table 2 are regularly flooded by diurnal tides and lie between 10 – 100 meters of the main water channels. However, the soils may be exposed for relatively longer periods during the dry season consequent to low water levels in the channel. Soils close to the channels show the least differentiation while soils of the creek and channel levees are much more differentiated. Large quantities of fibrous roots in the Creek Town profiles related to the dominance of *Nypa fruticans* as opposed to *Rhizophora racemosa* species which dominate the Calabar River swamp segment.

Table 3: Particle size composition, variability and texture in soil profiles of the Creek Town Creek/Calabar River swamps

Horizon	Sand (%)	Silt(%)	Clay(%)	Texture
(a) Creek Town Creek segment				
Surface	28.5 ± 0.7	47.5 ± 3.5	24.0 ± 2.8	Loam
C.V.(%)**	(2.5)	(7.4)	(3.3)	
Subsurface	31.7 ± 4.5	42.0 ± 4.4	26.3 ± 3.1	Loam
C.V.(%)	(14.2)	(10.5)	(11.8)	
(b) Calabar River segment				
Surface	31.5 ± 3.5	43.0 ± 4.2	20.5 ± 0.7	Loam
C.V.(%)	(11.1)	(9.3)	(3.4)	
Subsurface	44.3 ± 3.1	32.3 ± 6.0	23.3 ± 3.2	Loam
C.V.(%)	(7.0)	(18.6)	(13.7)	

*Each value is mean for at least five samples;**= coefficient of variation

Table 3 shows that generally the profiles from both river segments were essentially similar, being loamy both at the surface and subsurface. Sand, silt and clay fractions show appreciable increase with depth. However, variation in sand content proportion could be due to active currents that are capable of transporting coarse fragments into the swamps. Variation in silt and clay proportions is an indication of channel sedimentation and deposition of fine colluviums from the terrestrial freshwater zone. In the Creek Town segment, sand appears to be the most variable at the subsurface while in the Calabar River segment silt appears to be the most variable.

The sizes of swamps also affect profile characteristics of mangrove soils. In the relatively larger area of the Cross River mangrove swamp, three segments with observable differences in the flow characteristics of the channels could be demarcated (Tables 4 and 5). The varying profile characteristics are shown in Table 4. Soils of the Mangrove Islands are dominated by *Rhizophora spp.* and *N. fruticans,* and are the most regularly flooded by tides. Consequently, profile differentiation is absent in the subsurface. High root content which decreases with profile depth correlates with dense growth of *Nypa fruticans*. Along the estuarine shores at Okposo, profiles are not regularly inundated by tides because of the prominent levees along Widenham Creek. These profiles show significant differentiation, with the presence of mottled layers and ferruginous nodules at the subsurface. The Uya Oron segment is exposed for longer periods during low tides because of the narrow width of the channel. Here, profiles close to the channel do not show any differentiation but those further inland were weakly differentiated at the surface. The profiles carry mostly *Rhizophora racemosa* which probably account for the low fibrous root content.

The Kwa Iboe River swamp is marginal and contains two segments namely: (a) the Ibeno meander segment which lie along the main river channel; and (b) Stubbs Creek segment which lie along Stubbs Creek and other minor distributary creeks (tables 6 and 7). Both segments vary in hydraulic characteristics of the channels but are regularly flooded with *Avicennia africana* as the dominant species. Profile differentiation along both segments is slight. There is a high degree of stickiness and plasticity in all profiles which due to the occurrence of *Avicennia spp.* The *pneumatophores* of the species presumably aid entrapment of fine silt such that the profiles are almost fluid liquid mass. When dry the soils become extremely hard. Fragments of oyster shells are also observed in the profiles.

Table 4: Soil Profile description from segments of the Cross River mangrove swamps

	(a)Okposo segment		(b)Mangrove Islands		(c)Uya Oron	
Horizon	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
Colour (Munsell)	Very dark Brown (10YR2/2) - Very dark (10YR3/1)	Very dark grey (10YR3/1)	Very dark grey (10YR3/1)	Very dark grey (7.5YN3/0)	Very dark grey (10YR3/1) – dark grey (4YR4/1)	Very dark grey (10YR3/2 – Dark grey (5YR4/1)
Mottles (Munsell)	Yellow (10YR8/8)	-	Brownish yellow (10YR6/6)	Brownish yellow (10YR5/8)	Light reddish brown (5YR6/8)	Yellowish red (5YR4/6)
Root Content	2	1	3	0	1	0
Stickness	1	0	1	0	2	2
Plasticity	2	0	2	1	1	0
Structure	3, 4	4	1	2	2	4
Hardness	3	3	2	1	2	1

Table 5: Particle size composition, variability and texture in soil profiles of the Cross River swamps

Horizon	Sand(%)	Silt(%)	Clay(%)	Texture
(a) Mangrove Islands/UyaOron Segment*				
Surface	31.5 + 3.5	61.5 + 6.4	7.0 + 2.8	Silt loam
C.V.(%)	(11.1)	(10.4)	(40.0)	
Subsurface	28.3 ± 0.6	59.3 ± 5.5	13.3 ± 5.1	Silt loam
C.V.(%)	(2.1)	(103.8)	(38.3)	
(b) Okposo Segment				
Surface	33.5 ± 0.7	47.0 ± 1.4	25.0 ± 5.7	Loam
C.V.(%)	(2.1)	(3.0)	(22.8)	
Subsurface	35.3 ± 1.2	44.0 ± 3.5	20.7 ± 4.6	Loam
C.V.(%)	(3.4)	(8.0)	(22.2)	

*Each value is mean for at least eight samples

Comparatively, the point bars on the meanders of the Kwa Iboe River have higher silt and sand fractions than the Stubbs Creek profiles (Table 7). Noticeable difference occurs in the proportions of clay. While the Stubbs Creek profiles are loamy both at the surface and in the subsurface, the point-bar profiles are silt loam at the surface and loam in the subsurface. Subsurface variations are greater which indicate a gradient of particle size sorting by past fluvial processes. The large coefficient for clay indicate that much of the textural differences between the profiles relate to the clay content of the soils.

In the Imo River swamps, two broad segments could be identified: (a) the Opobo Town segment – which comprises all the creeks south of Ikot Abasi e.g. Tullifer Creek, Jaja Creek and Strongface Creek; and (b) the Ikot Abasi segment which comprises the Imo River channel together with the inter-tidal lagoons and ponds found in the upper estuary (Tables 8 and 9). The Opobo Town profiles carry mainly *Rhizophora spp.* and *N. fruticans*. The high root content of the surface soil relate to the occurrence of *Nypa* while the insignificant differentiation relate to regular flooding and submergence in each tidal cycle. However, there is a weak differentiation at the subsurface due to gradual increases in elevation such that ferric ions occur in the profiles. The shore profiles are characterized by the occurrence of whole oyster shells due to active sediment deposition. The Ikot Abasi segment are the most differentiated. Apart from the highly fibrous surface soil arising from the occurrence of *Acrostichum aureum*, there is also a distinct segregation of basic ferric ions with the mottles being prominent, many and coarse. The subsurface also show strong mottling with increasing stoniness to the 100 cm depth.

Table 6: Soil Profile description of the Kwa Iboe River swamps

	(a) Ibeno meander segment		(b)Stubbs Creek segment	
Horizon	Surface	Subsurface	Surface	Subsurface
Colour (Munsell)	Very dark grey (7.5YRN3) - dark grey (4YR4/1)	Very dark grey (10YR3/2)	Very dark grey (7.5YRN3)	Very dark grey (10YR3/1)
Mottles (Munsell)	-	Light reddish brown (5YR6/8)	-	-
Root content	1,2	0	0	0
Stickiness	3	3	2	3
Plasticity	3	2	2	2
Structure	1	2	3	3
Hardness	3	3	3	3

Table 7: Particle size composition, variability and texture in soil profiles of the Kwa Iboe River Swamps

Horizon	Sand (%)	Silt (%)	Clay (%)	Texture
(a) Stubbs Creek Segment*				
Surface	28.0 ± 2.8	48.5 ± 0.7	24.0 ± 2.8	Loam
C.V.(%)	(10.0)	(1.4)	(11.7)	
Subsurface	34.0 ± 5.7	46.0 ± 5.7	20.5 ± 0.7	Loam
C.V.(%)	(16.8)	(1.2)	(3.4)	
(b) Ibeno Meander Segment*				
Surface	32.5 ± 2.1	52.5 ± 0.7	15.0 ± 2.8	Silt loam
C.V.(%)	(6.5)	(1.3)	(18.7)	
Subsurface	35.0 ± 4.6	48.7 ± 6.4	17.7 ± 3.1	Loam
C.V(%)	(13.0)	(13.1)	(17.5)	

*Each value is mean for seven samples

Table 8: Soil profile description of the Imo River swamps

	(a)Opobo Town segment		(b)IkotAbasi segment	
Horizon	Surface	Subsurface	Surface	Subsurface
Colour (Munsell)	Very dark grey (5Y3/1)	Dark olive grey (5Y3/2)	Very dark grey (10YR3/1)	Very dark grey (7.5YRN3/0)
Mottles (Munsell)	-	Yellow (5Y7/8	Brownish yellow (10YR6/6 – 10YR5/8)	Brownish yellow (10YR5/8) white (2.5YN8/0)
Root content	2	0, 1	2, 3	2, 1
Stickiness	2	0, 1	1, 2	0
Plasticity	2	2	2	0, 1
Structure	1, 2	3, 4	1	1, 2
Hardness	3	3	1	1

The profiles consist of loam both at the surface and subsurface (Table 9). While there is a decrease in sand with profile depth in one segment, sand content increases appreciably with depth in the other. Also, silt content decreases with depth in the latter profiles. But the coefficients being generally low, is an indication that the profiles are relatively similar on this scale of the analysis.

The profiles so far discussed are those that carry mangroves in various complexities. Comparison could also be made between these profiles and tidal flats which, through the process of sedimentation and deposition may eventually evolve into mangrove habitats (Table 10).

Table 9: Particle size composition, variability and texture in soil profiles of theImo River swamps

Horizon	Sand(%)	Silt(%)	Clay(%)	Texture
(a) IkotAbasi Segment*				
Surface	41.0 ± 1.4	42.4 ± 0.7	16.5 ± 2.1	Loam
C.V.(%)	(3.4)	(1.6)	(12.7)	
Subsurface	34.3 ± 7.6	43.0 ± 11.3	22.7 ± 7.8	Loam
C.V.(%)	(22.2)	(26.3)	(35.5)	
(b) Opobo Town Segment*				
Surface	34.0 ± 1.4	48.0 ± 1.4	18.0 ± 2.8	Loam
C.V.(%)	(4.1)	(2.9)	(15.6)	
Subsurface	39.5 ± 0.7	43.5 ± 0.7	18.5 ± 0.7	Loam
C.V.(%)	(1.8)	(1.6)	(3.8)	

*Each value is mean for five samples.

Table 10: Particle size composition, variability and texture in tidal flat profiles

Horizon	Sand(%)	Silt(%)	Clay(%)	Texture
(a) Cross River Swamp*				
Surface	44.6 ± 2.8	21.0 ± 5.7	32.4 ± 2.8	Sandy clay loam
C.V.(%)	(6.2)	(27.1)	(8.6)	
Subsurface	59.3 ± 13.3	26.3 ± 6.1	14.4 ± 9.2	Sandy loam
C.V.(%)	(22.4)	(23.2)	(63.9)	
(b) Kwa Iboe River Swamp*				
Surface	46.0 ± 1.4	28.0 ± 1.4	25.5 ± 0.7	Sandy clay loam
C.V.(%)	(3.0)	(5.0)	(2.7)	
Subsurface	58.3 ± 13.3	25.0 ± 9.2	16.7 ± 4.2	Sandy loam
C.V.(%)	(22.8)	(36.8)	(25.1)	

*Each value is mean for four samples

Tidal flats are lower in silt but higher in clay than the vegetated profiles. Since both vegetated and bare surfaces are affected by the same tides, it implies that silt deposition is aided by the vegetation. Vegetation also reduces impact of waves such that fine sediments exported from the tidal flats at high tide are deposited in the swamps by ebb tides. High sand content of the profiles increases with depth, i.e. the coarser particles of swamp soils occur close to the channels. It seems obvious that with an increase in the elevation of tidal flats above tide level, silt deposition also increases which eventually facilitate the establishment of seedlings on the shores.

If the particle sizes distribution is categorized into three groups according to Wilding and Drees (1978) based on the coefficients of variation viz: CV < 15% (least); CV = 15 – 35% (moderate) and CV> 35% (most variable), then soils generally display least to moderate variations in particle size distribution. The profiles have obviously been formed from sediments transported from similar sources viz: the coastal plain sands. Mangrove soils show least differentiation with depth. The surface layer is characterized by abundant fibrous roots and semi-decomposed organic matter. The structure of wet soils is determined by the extent of saturation but when partially dry, the root system of the mangroves bind the soil strongly together. Where the rootmat is not extensive, the air dry soils are very hard. In cases where there is a high degree of stoniness, the soils tend to crumble on air drying. Distinct horizons are frequent in soils associated with more landward areas which may not carry true mangrove species. The differentiation therefore relates to the fluctuations in the water table from the shores inland. It may be interpreted that increased podsolization occurs in the more landward areas due to increased elevation above mean low tide which facilitates leaching.

Typical Mangrove Soil profiles

Based on field sketches and laboratory analysis, typical mangrove soil profiles and tidal flat profiles are illustrated in Figures 4-8. The dominant mangroves occurring on the profiles have been also indicated. There appears to be no profile which is exclusive to the dominant species found on it. Considerable differences are observed between profiles on which similar species occur. Other reports that attempt the simple correlation between profiles and species usually rely on isolated samples from groves of pure mangrove stands, e.g. Naidoo (1980). At this level of investigation, the development and structure of swamp profiles appear to be more related to dynamic geomorphology of the estuaries than to the reaction of the vegetation on the soils. However mangrove roots contribute significantly to the organic matter content of the profiles. Although spatial sequences in soil physical properties have been observed from the shores inland, e.g., increases in sand and clay proportions, soils of the tidal areas generally are similar. The soil contains large oyster shells in some samples, particularly those from mixed *R.*

racemosa/ R. mangle stands. In summary, the characteristic mangrove profile is slightly sticky and slightly plastic with a smooth feel at the surface and gritty feel in the subsurface. The slightly sticky profiles occur across all tidal segments of the swamps but could be mostly associated with fringing *Avicennia* and *Rhizophora* species. Very plastic, not/slightly plastic, and not sticky occur in relatively few profiles. Most profiles are very hard when dry while a few are hard and moderately hard, crumbling to the component structure on air drying.

The slight sequence in the differentiation of profiles between the shoreline and the inner swamp is due to an environmental gradient of leaching. The gradient is related to the youthful nature of mangrove soils which have impaired drainage as opposed to profiles of the inner swamps. Peat profiles associated with tidal mangroves are less differentiated than the inland profiles. Therefore if a correlation is established between the presence of mangrove, and soil profile differentiation, it may not necessarily imply a causal relationship. Increases in sand fractions of certain profiles in the inner swamps reflect the contribution of terrestrial sediments rather than of the wetland environment. Occurrences of mangroves in the swamps also relate to efficiency of dispersal mechanisms of the species. However, most tidal imports into the mangrove zone are basically organic with fine silt which favors mangrove growth along sheltered shores with low wave energy.

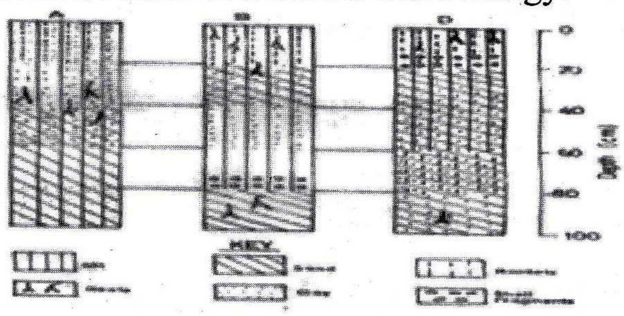

Fig.4: Typical soil profiles from stands dominated by *Rhizophora racemosa* species. A = Creek Town Creek/Calabar River swamp; B = Cross River swamp; D = Imo River swamp.

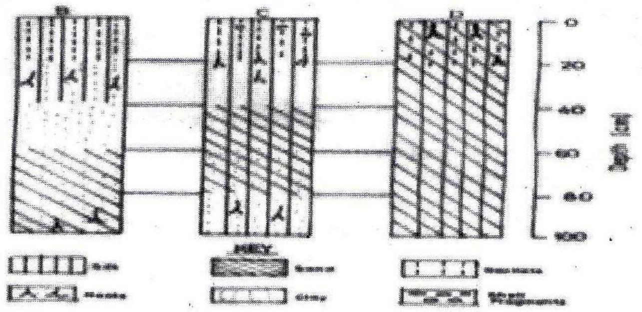

Fig.5: Typical soil profiles from stands dominated by *Avicennia africana* species. B = Cross River swamp; C = Kwa Iboe River swamp; D = Imo River swamp.

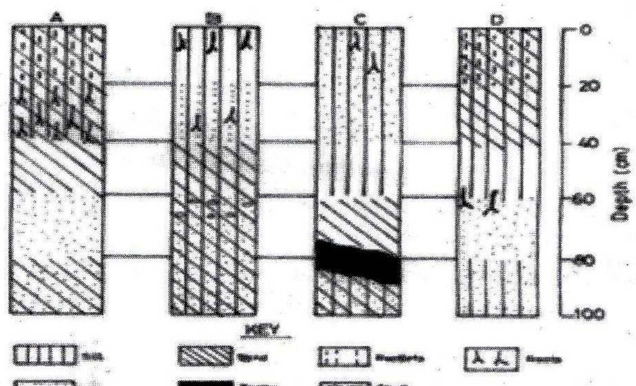

Fig.6: Typical soil profiles from stands dominated by *Rhizophora mangle* species.
A= Creek Town Creek/Calabar River swamp;
B= Cross River swamp;
C= Kwa Iboe River swamp; D= Imo River swamp.

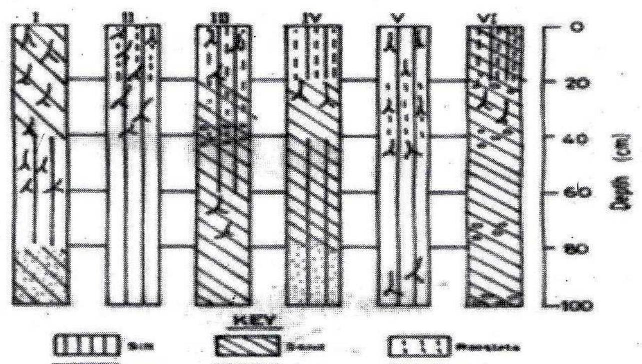

Fig.7: Typical soil profiles from stands dominated by I= *Nypa fruticans* (Creek Town Creek/Calabar River swamp); II = *Pandanus candelabrum* (Cross River swamp); III= *Acrostichum aureum* (Kwa Iboe River swamp);
IV= *Rhizophora harrisonii*, V= *Phoenix reclinata* (Imo River swamp);
VI= *Sesuvium portulacastrum* (Kwa Iboe River swamp).

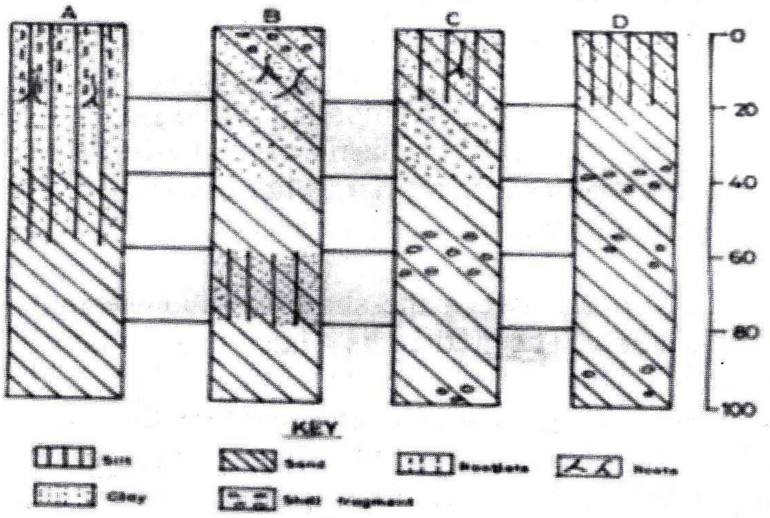

Fig.8: Typical soil profiles from unvegetated tidal flats. A= Creek Town Creek/Calabar River swamp; B= Cross River swamp; C= Kwa Iboe River swamp D= Imo River swamp.

Most Mangrove soil profiles show clay illuviation except the beachridge which are relatively recent consisting of very sandy material (Fagbami *et al.*, 1981, Ukpong, 1992). The coarsest material occurs on the beach ridge sand. In the estuarine area, the sediment is medium fine with the highest silt and clay percentage. There is also a longitudinal gradient in the particle size distribution. The lower estuarine levee materials are fine-textured (highest silt plus clay) than the upper delta levee materials. Laterally, the levee has a coarser textural grade than the levee slope. The sediments that are being deposited consist of clay, silt and fine sand which are spread over the flood plains by the flood water. The data from the Nigerian mangrove soils differ from those reported for other mangrove soils in Africa. In South Africa, Naidoo (1980) reported predominantly clayey soils with large sodium concentration. These differences are probably due to local geogenetic parameters and habitat variables such as physiography, mineralogy of adjacent coastal areas, and frequency of tidal inundation, salinity and salt spray.

Soil salinity in Mangrove swamps

Most studies on the salinity of mangrove swamps have been concentrated on the surface and subsurface water (Semeniuk, 1983). These studies have complimented laboratory experiments which attempt to evaluate salt tolerance by mangroves based on the osmotic relationship between mangrove roots and salinity. Surface water salinities are extremely variable, with the values being lower than soil salinities. In the River Niger Delta, Fagbami *et al.,* (1988) found that surface water salinity values vary from 4.2 to 29.5% between the brackish water zone and the sea while soil water salinity ranges from 10.9 to 35.4% between the same zones.

The mean salinity values in the swamp soils are shown in Tables 11 and 12. There is considerable vertical salinity gradient in mangrove soils. However, while values tend to increase with depth in some swamps, others show a decrease. Variation in surface and subsurface is least and similar for all swamps.The salinity values indicate a variation that is related to the size of swamp and spatial location from tidal influence. Values for the Cross River swamps are higher than the values for the Creek Town/Calabar River swamps. Large estuaries and proximity to the ocean permit wider tidal incursions. The estuary also situates close to the ocean. Therefore the spatial variation between two segments is well marked and only a very slight vertical gradient may be observed in the values (Table 12).

Table 11: Soil salinity in mangrove swamps*

	Creek Town Creek/Calabar River	Cross River	Kwalboe River	Imo River
Horizon	Salinity (%)	Salinity (%)	Salinity (%)	Salinity (%)
Surface	3.8 ± 0.04	5.3 ± 0.30	4.2 ± 0.24	5.2 ± 0.16
C.V.(%)	1.1	5.6	5.7	3.0
Subsurface	4.3 ± 0.23	4.8 ± 0.08	4.3 ± 0.28	4.9 ± 0.33
C.V.(%)	5.3	1.7	6.5	8.3

*Each value is mean for ten samples

Table 12: Variability of Soil salinity among major segments of the mangrove swamps

(a)Creek town Creek / Calabar River swamps				
	Creek Town segment		Calabar River segment	
Horizon	Salinity (%)	CV (%)	Salinity (%)	CV(%)
Surface	4.2 ± 0.01	0.2	3.4 ± 0.08	2.5
Subsurface	4.6 ± 0.37	8.1	4.1 ± 0.13	3.1
(b)Cross River swamps				
	Mangrove Islands/UyaOron		Okposo segment	
Surface	5.3 ± 0.14	2.72 ± 0.47	8.9	
Subsurface	5.3 ± 0.10	1.9	4.3 ± 0.16	3.6
(c)Kwalboe River swamps				
	Ibeno Meander segment		Stubbs Creek segment	
Surface	4.1 ± 0.27	6.6	4.4 ± 0.22	5.0
Subsurface	4.1 ± 0.14	3.4	4.4 ± 0.51	11.6
(d)Imo River swamp				
	IkotAbasi segment		Opobo Town segment	
Surface	4.2 ± 0.26	6.2	6.1 ± 0.06	1.0
Subsurface	4.1 ± 0.27	6.6	5.7 ± 0.42	7.4

Variability of Soil chemical properties in the swamps

In Mangrove swamps, soil chemical properties show considerable variation in values. The ecosystem apparently is unstable with regard to the hydro chemical properties. Table 13 shows that in some segments the most variable property is sodium while the least varied are magnesium and calcium. The subsurface soil varies less than the surface soil in most cases. In other swamps, organic carbon, calcium and phosphorus show high variability. Generally most soil properties show greater variability at the surface than in the subsurface. The least varied is magnesium at the surface and subsurface in profiles that are under regular marine influence e.g. beach ridges.

The variability of some micronutrients is shown in Table 14. The least varied property within is zinc while manganese and copper are moderately varied. Acid properties (including pH) also show considerable variation within and between the swamps (Table 15). The least varied in tidal swamps is pH but moderate on the coastal beach ridge. Soluble sulphate is moderately and highly varied. The observed variation indicate that the mangrove swamps are not homogeneous in the chemical composition. pH values are low as are usually associated with mangrove soils . Values of soluble sulphate and aluminum are large and may have been the main contribution to exchange acidity.

The micronutrients show moderate variation except zinc which shows the least variation. The relatively large organic carbon contents are indicative of the peaty nature of soils and preponderance of roots and pneumatophores. The Mangrove soils have a high capacity to absorb cations, particularly magnesium which may be due to the abundance of magnesium in sea water. Exchangeable sodium and calcium are large whereas potassium is comparatively small. Because the soils are appreciably acidic, phosphorus is probably fixed by iron and aluminum.

Table 13: Variability of some soil chemical properties at two depths (0-20cm, 20-60cm) in mangrove swamps, including the coastal beachridge*

Properties	Creek Town/ Calabar River		Cross River		Kwalboe River		Imo River		Coastal ridge	Beach
	X ± SD	CV (%)	X ± SD	CV (%)	X ± SD	CV (%)	X ± SD	CV(%)	X ± SD	CV (%)
Organic C	4.0 ± 1.1	28	7.2 ± 4.4	61	4.7 ± 1.7	36	6.1 ± 2.4	39	3.5 ± 0.1	4
(%)	3.3 ± 1.0	30	5.1 ± 2.5	49	3.8 ± 1.5	39	5.8 ± 1.9	33	0.5 ± 0.1	2
CEC	26.7 ± 4.0	15	33.3± 10.5	32	50.0 ± 8.2	16	53.8 ± 7.5	14	11.4± 2.1	18
(me/100g)	30.1 ± 3.7	12	29.5± 7.2	24	44.6 ± 5.1	11	49.3 ± 2.3	5	18.3± 1.8	10
Calcium	9.4 ± 1.9	20	10.3± 7.5	73	15.5 ± 1.9	12	16.6 ± 4.2	25	1.7 ± 0.1	6
(me/100g)	11.2± 0.8	7	9.4 ± 2.5	27	14.8 ± 0.5	3	24.3 ± 1.5	6	1.5 ± 0.5	33
Magnesium	14.2± 1.2	9	18.6± 4.7	25	24.3 ± 1.4	6	25.6 ± 2.0	8	6.5 ± 0.1	2
(me/100g)	15.3± 0.9	6	21.4± 1.2	6	24.8 ± 1.5	6	24.3 ± 2.5	10	8.2 ± 0.5	6
Potassium	0.14± 0.4	28	0.24± .08	33	0.26 ± .06	23	0.20 ± .09	45	0.38± 0.1	26
(me/100g)	0.14± .05	35	0.32± .05	15	0.28 ± .08	28	0.22 ± .02	9	0.39± 0.1	26
Sodium	11.8± 5.4	46	11.6± 3.2	28	14.6 ± 4.1	28	12.0 ± 2.4	20	11.3± 4.4	39
(me/100g)	12.1± 3.1	26	13.6± 1.8	13	15.7 ± 3.5	22	14.3 ± 1.7	12	6.8 ± 2.3	34
Available P	5.1 ± 0.6	12	3.9 ± 0.6	15	2.2 ± 0.8	36	2.7 ± 0.8	30	5.0 ± 1.2	24
(ppm)	4.9 ± 1.5	31	2.8 ± 0.5	18	3.4 ± 1.5	44	4.2 ± 0.6	14	3.9 ± 1.8	46
Carbonate	6.3 ± 1.3	21	7.5 ± 1.2	16	4.9 ± 1.7	35	5.0 ± 1.8	36	11.0± 0.4	4
(gm/100g)	6.8 ± 0.9	13	6.8 ± 1.2	18	5.3 ± 1.4	26	6.5 ± 0.9	13	11.5± 0.5	5

*Each value is mean for six samples

Mangrove soils and species distribution

Three basic types of soils are usually associated with mangrove habitat evolution and substrate transformation namely, siliceous sands, calcareous sands and calcareous mud. These soils being mostly sedimentary in origin therefore are primary soils. Soil texture is important as an explanatory factor for the distribution of organisms in the swamps e.g. sesarmid crabs (Ballerini *et al.*, 2000, Canniicci *et al.*, 2000). Studies on rooting of mangrove species suggest that soil texture also influence the distribution of the species (Dahdouh-Guebas *et al.*, 2001). Other edaphic characteristics are also important explanatory factors (Ukpong 1994, 1997a, 1998, 2007).

Table 14: Variability of Soil micronutrients in Mangrove swamp soils*

Properties	Creek Town/ Calabar River		Cross River		Kwa Iboe River		Imo River		Coastal Beach ridge	
	Mean ± SD	C.V. (%)	Mean ± SD	C.V. (%)	Mean ± SD	C.V. (%)	Mean ± SD	C.V. (%)	Mean ± SD	C.V (%)
Copper (ppm)	3.3 ± 1.5	45	3.8 ± 0.8	21	3.6 ± 1.2	33	1.0 ± 0.3	30	0.2 ± 0.1	50
Iron (ppm)	1114.0 ± 128.5	12	2140.5 ± 1032.2	48	1732.6 ± 808.3	47	1261.4 ± 157.0	12	636.2 ± 84.6	13
Manganese (ppm)	338.5 ± 1026	30	228.6 ± 81.5	36	432.5 ± 121.3	28	346.2 ± 148.3	43	598.7 ± 72.8	12
Zinc (ppm)	43.1 ± 7.3	17	32.4 ± 5.5	11	38.7 ± 3.8	10	86.2 ± 10.2	12	42.8 ± 1.6	4

*Each value is mean for 10 samples, except the coastal beach ridge with mean for three samples.
All properties measured at depth 0-60cm

Table 15: Variability of acid properties in Mangrove swamp soils*

Properties	Creek Town/ Calabar River		Cross River		Kwa Iboe River		Imo River		Coastal Beachridge	
	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
pH	3.3 ± 0.3	9	3.1 ± 0.2	6	3.9 ± 0.4	10	4.0 ± 0.6	15	4.4 ± 1.2	27
Exchange acidity (me/100g)	1.4 ± 0.2	14	6.9 ± 1.8	26	4.0 ± 0.5	13	0.2 ± 1.2	19	0.6 ± 0.2	33
Aluminum (me/100g)	0.08 ± 0.02	25	0.08 ± 0.04	50	0.14 ± 0.06	43	0.12 ± 0.03	25	0.10 ± 0.04	40
Soluble sulphate (me/100g)	0.08 ± 0.03	38	0.12 ± 0.03	25	0.05 ± 0.02	40	0.07 ± 0.03	43	0.09 ± 0.06	67

*Each value is mean for 10 samples, except the coastal beach ridge with mean for three samples.
All properties measured at depth 0-60cm.

Cation exchange capacity (CEC) is usually high for most mangrove soils, the average of observations being 23.7 to 83.3 me/100g for *Avicennia* soil and 41.0 to 67.7 me/100g for *Bruguiera* soils (Naidoo, 1980). Ukpong (1997c) recorded values ranging from 44.6 ± 8.3 to 48.2 ± 10.2 me/100g in *Avicennia* soils and 29.8 ± 4.7 to 34.6 ± 8.2 me/100g in *Rhizophora mangle* soils. Magnesium and calcium were the predominant cations while sodium and potassium were comparatively lower. Generally calcium values decreased with soil depth except in *A. africana* and *R. mangle* soils. The values ranged from 7.2 ± 4.1 me/100g to 21.3 ± 6.8 me/100g in *A. africana* soils (Ukpong 1997a). The mangrove soils have a potentially high sink for cations especially in terms of exchangeable sodium and magnesium (Naidoo 1980), and calcium (Ukpong 1997c). A general trend is that CEC increases with distance landwards in the *Avicennia* zone. On the other hand, *Bruguiera* soils are lower in sodium, magnesium, calcium and potassium than *Avicennia* soils. However, this trend seems to be governed by proximity to the sea in Durban, South Africa and hence to frequency of tidal inundations as well as dilution from freshwater sources (Naidoo 1980). The high ratio of exchangeable magnesium and calcium and the low ratio of sodium to the extractable bases recorded by Ukpong (1992) in Nigeria indicate a strong influence of overland flow and subsurface fresh water inputs in the swamps. Similar trends have been reported for values of chloride 1.9 – 87.0 %; carbon 0.05 – 11.9 per cent and C/N ratio 0.4 – 36.0 in various mangroves. Soils associated with *Rhizophora* species have higher nitrogen, phosphorous and carbon content than *Avicennia* soils.

The chronosequence of the variation in soil properties from the shorelines to the inner swamps and their vertical gradients with substrate depth have for long been investigated by other researchers. Studies by Naidoo (1980) and Semeniuk (1983) indicated that there tend to be a general increase in clay and silt proportions of mangrove soils from the coastal margins inland. Carbonate content is noted to be high in most swamp soils perhaps due to the large mollusk population usually associated with saline or brackish coastal swamps. From observations, estuarine mangrove soils have lower carbonate content than soils of the sea coast littoral. Inferentially mollusks which contribute to the high carbonate content are more *marine* in nature than brackish in their choice of habitat.

Table 16: Bulk density, field moisture, particle size distribution, texture and colour values of mangrove soils

Sample depth (cm)	Bulk density (gcm^{-3})	Field moisture (%)	Particles size distribution(%) Sand	Silt	Clay	Texture	Colour
P_1: *Nypa fruticans*, 10m from Creek Town Creek							
0-20	0.72	134	32	44	24	Loam	2.5Y3/2
20-30	0.78	133	32	48	20	Loam	2.5Y3/2
40-60	0.76	123	30	48	22	Loam	2.5Y3/3
60-80	0.79	118	30	56	14	Silt loam	5Y2.5/2
80-100	0.75	112	40	30	30	Clay loam	5Y2.5/2
P_2: *Nypa fruticans/Rhizophora mangle*, 40m from Creek Town Creek							
0-20	0.73	125	26	46	28	Clay loam	2.5Y3/2
20-30	0.68	105	24	52	24	Silt loam	2.5Y3/2
40-60	0.72	98	24	40	36	Clay loam	2.5Y3/2
60-80	0.79	98	34	34	32	Clay loam	2.5Y3/2
80-100	0.78	86	32	44	24	Loam	2.5YN2/0
P_5: *Rhizophora mangle*, 100m from tributary Creek							
0-20	0.85	137	46	16	38	Sandy clay loam	2.5Y3/2
20-30	0.88	137	40	24	36	Clay loam	2.5Y3/2
40-60	0.89	128	46	42	12	Loam	2.5Y3/2
60-80	0.81	113	38	44	18	Loam	2.5Y3/2
80-100	0.84	96	46	38	16	Loam	5Y3/1
P_6: *Rhizophora racemosa*, 40m from Calabar River Channel							
0-20	0.74	140	32	50	18	Loam	5Y3/1
20-30	0.86	142	45	35	20	Loam	5Y3/1
40-60	0.88	120	43	33	24	Loam	5Y3/1
60-80	1.01	115	49	27	24	Sandy clay loam	5Y3/1
80-100	1.04	98	49	23	28	Sandy clay loam	5Y3/1

Bulk density values of mangrove soils ranged from 0.72 to 1.08 g cm^{-3} and values tend to increase with profile depth. The lowest values ranging from 0.72 to 0.79 g cm^{-3} occur in soils associated with *Nypa fruticans* and mixed stands of *N. fruticans/Rhizophora mangle*. Slightly higher values ranging from 0.81 to 0.89 g cm^{-3} occur in *Rhizophora mangle* soil. High bulk densities occur in *Nypa fruticans/Raphia* soil and *Rhizophora racemosa* soil relate to the high sand content in the soils (Table 16) (Ukpong, 1995a).

The organic matter content of mangrove soils tends to vary in a regional context and may be attributed to variations in species occurrences and species density in the different geographical regions. Organic matter content decreases appreciably with depth and with distance from the shores although these may not be an exclusive situation. Increase in organic matter content from the shores also correlate with increasing tree height and foliage. Ukpong (1995a) observed that organic carbon values decreased with sample depth and with distance inland in *Rhizophora* spp soils. *Nypa fruticans* soils and *Nypa fruticans/Raphia soils* had high mean values (5.1±1.6%; 5.2±1.5%) presumably due to the extensive fibrous roots of *Nypa* and *Raphia* palms. Low organic carbon occurred in *R. racemosa /N. fruticans* soil, corresponding with low species density and crown cover (Table17).

Table 17: Organic carbon, cation exchange capacity, exchangeable cations and available phosphorus associated with species and distances from water channels

Sample depth (cm)	Organic carbon(%)	CEC (me/100g)	Exchangeable cations (me/100g) Ca Na		Mg	K	P (µg ml[-1])
P_1: *Nypa fruticans*, 10m from Creek Town Creek							
0-20	6.8	34	14	19	0.10	0.20	1.95
20-30	5.9	36	13	21	0.07	0.30	1.15
40-60	5.9	36	15	19	0.06	0.37	0.99
60-80	4.1	41	15	22	0.05	0.40	0.56
80-100	2.8	42	15	23	0.07	0.43	0.90
P_2: *Nypa fruticans/Rhizophora mangle*, 40m from Creek Town Creek							
0-20	5.6	29	9	18	0.07	0.18	1.36
20-30	4.9	26	6	18	0.09	0.26	0.64
40-60	4.0	23	8	13	0.06	0.29	1.14
60-80	4.4	33	9	20	0.04	0.43	1.22
80-100	4.4	40	11	24	0.08	0.46	0.90
P_5: *Rhizophora mangle*, 100m from tributary Creek							
0-20	3.4	31	12	12	0.14	0.38	2.93
20-30	3.8	28	10	13	0.07	0.42	1.18
40-60	3.6	36	12	19	0.09	0.07	2.36
60-80	3.8	32	13	15	0.06	0.11	2.68
80-100	3.8	31	11	21	0.03	0.28	1.93
P_6: *Rhizophora racemosa*, 40m from Calabar River Channel							
0-20	3.8	27	8	17	0.10	0.60	2.06
20-30	4.2	27	8	15	0.14	0.88	2.36
40-60	3.6	23	7	13	0.07	0.70	2.08
60-80	4.8	33	9	20	0.05	0.92	2.41
80-100	3.6	36	8	25	0.06	0.51	1.64

Naidoo (1980) had observed that most mangrove soils in the humid tropics are moderately acidic. But on semi-arid coastlines, acidity could be much higher Also, varying pH values have been observed between species zones, for example, Naidoo (1980) found that pH values in *Avicennia* zones range from 4.6 to 6.4 while in *Bruguiera* zones, the range varies between 5.6 and 6.1. *Rhizophora* soils have lower pH values and contents of oxidisable sulphur than *Avicennia* soils. The pH values have decreased with air drying of soils which implies that irregularly inundated swamps and dry spells of climate may cause the soils to acquire higher acidity than would normally be the case under uniformly wet conditions. Variable acidity conforms to the occurrence of different mangrove species. On air drying, soils associated with *Rhizophora* species have lower pH values than soils associated with *Avicennia* species. Fagbami *et al.,* (1988) also found out that from the sea towards the fresh water zone in mangrove areas, pH values increase appreciably, ranging from 6.4 to 7.9. Ukpong (1995b, 1997b)(Table 18) observed that exchangeable aluminium is more abundant in soils associated with pure stands of *Nypa fruticans, Rhizophora mangle* and mixed stands of *Rhizophora* spp. and *Acrostichum aureum*, than in those under *Pandanus candelabrum* and *Avicennia africana* (table 19). Large amounts of soluble sulphate also occur in *Rhizophora* spp. and *Nypa* soils. Generally, soils associated with *A. africana* have higher pH values and less exchangeable acidity than soils associated with *Rhizophora* and *Nypa.*

Agricultural potentials

Large areas of mangroves have been reclaimed for fish farms particularly shrimps in Singapore and other SE Asian nations. Shrimp farming is also being practiced in the mangrove zone in Nigeria. In Nigeria and in Sierra Leone the soils have at various times been tested for the growth of rice, perhaps with insufficient knowledge of the ecology of the mangrove swamps.

Fluctuations in the salt content of river water could make conditions in tidal swamps which border the river suitable for the growth of rice (Ukpong 1995a). If the fresh water period is long enough, short–duration rice could be transplanted and grown and in the dry season, the slightly higher salinities restrict the growth of weeds.

For cultivation of rice, two areas of mangroves may be used, namely:
Areas that have poor drainage, but lying close to rivers or water channels. Such areas may have higher soil salinities in the dry season than in the wet season when salt is leached by fresh water.

Table 18: Acid properties of mangrove swamp soils associated with species and with distances from water channels

Sample depth (cm)	pH Field moist	pH Air dry	Exchange acidity (me/100g)	AI (me/100g)	SO_4 (me/100g)
P_1: *Nypa fruticans*, 10m from Creek Town Creek					
0-20	6.5	5.6	1.2	0.29	0.05
20-30	6.5	5.5	1.2	0.25	0.05
40-60	6.6	5.2	1.4	0.40	0.08
60-80	6.6	5.0	3.4	0.29	0.07
80-100	6.8	5.5	2.4	0.18	0.07
P_2: *Nypa fruticans/Rhizophora mangle*, 40m Creek Town Creek					
0-20	5.6	4.7	1.1	0.28	0.04
20-30	5.4	4.8	1.1	0.22	0.04
40-60	5.5	4.5	1.0	0.25	0.05
60-80	5.6	4.3	2.3	0.38	0.06
80-100	5.8	4.4	2.8	0.20	0.08
P_5 *Rhizophora mangle*, 100m from tributary Creek					
0-20	5.4	4.8	3.7	0.26	0.03
20-30	5.7	4.6	3.8	0.26	0.04
40-60	5.5	4.8	4.1	0.25	0.05
60-80	5.8	4.6	4.2	0.29	0.07
80-100	5.9	4.7	4.6	0.21	0.10
P_6: *Nypa fruticans/Rhizophora mangle*, 40m Creek Town Creek					
0-20	5.7	4.1	2.4	0.27	0.06
20-30	5.9	4.4	2.3	0.21	0.06
40-60	5.8	4.2	2.4	0.21	0.06
60-80	5.9	4.1	2.4	0.22	0.07
80-100	5.6	4.5	2.6	0.27	0.07

Areas adjoining small drainage basins e.g. creeks or out-off lagoons where large volumes of fresh water do not flow down them in the wet season so that the soil remains consistently saline. Both types of swamps may be empoldered or drained for rice production. In the first type of swamp, channels could be constructed to improve access of wet season tides to further lower soil salinity. In the second type, tides must be excluded during the growing season and rice cultivated as rain-fed crop. To reclaim saline swamps, the tidal water might be excluded at all times or during the actual growing period for rainfall to reduce the salt contents of the surface soil to a satisfactory level. But the exclusion of tidal water at all times may lead to drying of the soil particularly during the dry season and produce adverse soil conditions (Table 18 and 19). After air-drying for 30 days, soil pH could be as low as 2.2. Ukpong (1995) observed that pH of mangrove soils increased with profile depth and with decreasing fibrous root content. On air drying, soil pH decreased more in profiles with large fibrous root contents (e.g. *N. fruticans* and *Rhizophora spp* Soils) than in *Avicennia* and *Pandanus* soils, with smaller fibrous root contents.
Rhizohora and *Nypa* possess extensive capillary root systems, which tend to produce fibrous

peat soils, whereas *Avicennia* and *Pandanus* have poorly developed root systems which do not produce peat. The rate of root decomposition depends on pH and the extent to which the soils undergo repeated wetting and drying. Upon drying the sulphides may oxidize to sulphates. However in wetter conditions, where tides are regular and the soils rarely subjected to long periods of aeration, the process of root decomposition and acid formation is slow. Therefore if the soils are allowed to dry out, acidity and exchangeable aluminum and soluble sulphate increase rapidly. Ukpong (1995a) in SE Nigeria observed air-dry pH values ranging from 3.5 to 4.2 after 10 days of air drying while the corresponding field- moist values ranged from 5.8 to 6.0 (see Table 19).

The fall in pH could be attributed to the liberation of free HCl or the oxidation of ferrous sulphide which produces free H_2SO_4. However, apart from the soil being extremely hard after air-drying or empoldering, the mangroves species themselves may be used as satisfactory indicators of the soil conditions prior to cultivation. The method may involve investigating the soils under various types of mangrove species in relationship to an empoldering scheme. Soil associated with *Avicennia africana* and *Pandamus candelabrum* have higher pH values and less fibrous root content, exchangeable aluminum, soluble sulphate and exchangeable acidity than soils associated with *Rhizophora spp* and *Nypa*. Hence the *Rhizophora* and *Nypa* soils should not be drained and allowed to dry. Unless crops are known to tolerate highly acid conditions, very fibrous soils should not be reclaimed for cultivation.

Rationale for management of mangroves

Apart from their potentials for cultivation, there are many reasons why mangrove swamps should be conserved and managed properly. Macintosh and Ashton (2002) summarise these reasons as follows:

To protect the unique bio-diversity of mangroves

The unique and valuable range of services and functions provided by mangrove forest ecosystems make them far more valuable than the sum of the products they generate

Infact, Mangrove ecosystems can provide services that are significantly higher in value relative to alternative man made uses of land. There are still many aspects of mangrove bio-diversity that are not known and may provide further benefits to man To contribute to increased scientific knowledge through research on functional linkages Degradation of the mangrove ecosystem has had important environmental impacts on physico-chemical, biological and ecological properties that are sometimes not reversible. There are complex linkages and interactions between the mangroves and other ecosystems and processes both upstream and downstream of the Mangrove forest zone

Table 19: Acid properties and fibrous root content of some representative mangrove soil profile

Sample depth (cm)	pH (field moist)	pH (air dry)	Fibrous root (%)	Al	SO4 (me/100 g)	Exchangeable acidity
Nypa fruiticans(CV: 100%)						
0 – 20	5.8	3.5	13.5	0.28	0.19	0.91
20 -40	5.9	3.5	8.6	0.29	0.17	0.90
40-60	6.0	3.6	6.7	0.27	0.18	1.00
Avicennia afriana/Nypa fruiticans(CV: 45%/30%)						
0 - 20	6.6	4.8	6.4	0.18	0.06	0.51
20 - 40	6.6	4.9	5.6	0.19	0.08	0.48
40 -60	6.8	4.9	3.2	0.15	0.05	0.42
Rhizophora / Nypa fruiticans(CV: 40%/30%)						
0 – 20	5.5	3.3	16.8	0.25	0.15	1.61
20 -40	5.5	3.2	13.8	0.26	0.14	1.52
40 - 60	5.7	3.4	7.6	0.29	0.15	1.72
Rhizophora mangle (CV: 100%)						
0 – 20	5.3	2.9	15.2	0.26	0.16	1.20
20- 40	5.4	3.2	8.4	0.26	0.18	1.22
40 -60	5.7	3.2	4.6	0.25	0.14	1.01
Raphia timifera /Rhizophora spp(CV 50%/45%)						
0 – 20	5.3	3.7	12.6	0.26	0.16	1.10
20 -40	5.5	3.7	11.9	0.28	0.17	1.32
40 -60	5.5	3.8	10.2	0.28	0.12	1.20
Pandanus candelabrum (CV: 100%)						
0 – 20	5.9	4.6	3.5	0.15	0.05	0.54
20 - 40	5.9	4.5	3.2	0.15	0.05	0.54
40 - 60	5.8	4.3	2.5	0.17	0.09	0.48

Protection of mangroves in their natural state provides an attractive habitat and species for sustainable, nature-based tourism, which is becoming a world industry and provides major benefits to local communities

A refuge for intensely exploited or threatened species

Protection of cultural diversity and livelihoods

The fundamental objective of Mangrove management is to promote conservation, rehabilitation and sustainable utilization of mangrove ecosystems (Macintosh and Ashton 2003). The objectives can be achieved by:

-Taking the precautionary approach to the management of mangrove ecosystems

-Adopting the ecosystem approach to the conservation of mangroves and associated watersheds and coastal ecosystems, including trans-boundary areas.

-Identifying and protecting biodiversity hot spots and endangered species and habitats associated with mangrove ecosystems.

-Recognising and supporting the special needs of traditional mangrove communities and other mangrove resource users.

-Mitigating adverse environmental impacts on mangrove ecosystems caused by human activities and natural phenomena.

-Rehabilitating or restoring areas of destroyed or degraded mangroves through natural regeneration, assisted if necessary by active intervention, including restoring the hydrological regime and/or planting mangroves.

It is important that countries and all those engaged in mangrove management adopt measures for the sustainable use of mangrove resources based on sound knowledge, supported by appropriate policy, legal and institutional frameworks. Conservation and other management measures at all levels should therefore take into account traditional knowledge and cultural values, together with the best available scientific information. Such measures should be designed to ensure the long-term sustainability of mangrove resources.

REFERENCES

Boto, K.G and Wellington, J. T. (1984). Soil characteristics and nutrient status in a Northern Australian mangrove forest. *Estuaries*, 7: 61-69.

Davis, J. H.(1940a). The ecology and geological role of mangroves in Florida. *Carnegie Inst Wash. Publ.* No. 517, Pp. 303 – 412

D'Hoore, J. (1963). Soil Map of Africa (5th revision) *C.C.T.A./C.S.A. Joint project.* No. 11

Ballerini, T., Macia, A. and Cannicci, S. (2000). Zonation of mangrove crabs at Inhaca Island, Mozambique: a new hypothesis. Abstract Volume of the Meeting on Mangrove Macrobenthos. 7-11 Sept., 2000. Mombasa, Kenya.

Cannicci, S., Skov, M. W and Vannini, M (2000). The influence of biotic and abiotic factors on the distribution of mangrove crabs at Milda Creek, Kenya: a multivariate approach. 7-11 Sept., 2000. Mombasa, Kenya.

Cintron, G., A. E. Lugo, O. J. Pool and G. Norris (1978). Mangroves of arid environments in Puerto Rico and adjacent islands. *Biotropica* 10:110 – 121

Fagbami, A. A., E. J. Udo and C. T. I. Odu (1988). Vegetation damage in an oil field in the Niger Delta of Nigeria *J. Trop. Ecol.* 4:61 – 75.

Giglioli, M.E.C. and I. Thornton (1965a). The mangrove swamps of Keneba, Lower Gambia River Basin I. Descriptive notes on climate, the mangrove swamps and the physical composition of their soils. *J. Appl. Ecol.* 2:81 – 104.

Giglioli, M.E.C. and I. Thornton (1965b). The mangrove swamps of Keneba, Lower Gambia River Basin II. Sulphur and pH in the profiles of swamp soils *J. Appl. Ecol.* 2: 251 – 269.

Dahdouh-Guebas, F., Kairo, J. G., Jayatissa, S., Cannicci, S., and Koedam, N (2002). An ordination to view vegetation structure dynamics in disturbed and undisturbed mangrove forests in Kenya and Sri Lanka. *Plant Ecology* 161: 123-135.

Macintosh, D. J. and Ashton, E. C. (2002). A Review of Mangrove Biodiversity Conservation and Management. Centre for Tropical Ecosystems Research, University of Aarhus, Denmark

Macnae, W. (1968). A general account of the fauna and flora of mangrove swamps and forests in the Indo-Pacific region. *Adv. Mar. Biol.* 6:73-270.

Naidoo, G. (1980). Mangrove soils of the Beachwood area Durban. *J. South Afr. Bot.* 46:293-304.

Semeniuk, V. (1983) Mangrove distribution in Northwestern Australia in relationship to regional and local freshwater seepage. *Vegetation*: 53 11 – 31

Tomlinson, T. E. (1957a). Relationship between Mangrove vegetation, soil texture and reaction of surface soil after empoldering saline swamps in Sierra Leone. *Trop. Agric. Trin.* 34: 41 – 50.

Ukpong, I. E. (1989) An evaluation of the ecological status and environmental relation of mangrove swamps in South eastern Nigeria. Ph.D Thesis, Department of Geography, University of Ibadan, Nigeria.

Ukpong, I. E. (1994) Soil-vegetation interrelationships of mangrove swamps as revealed by multi-variate analyses. *Geoderma* 64: 167-181.

Ukpong, I. E. (1995a) Mangrove soils of the Creek Town Creek/Calabar River swamp, Southeastern Nigeria. *Tropical Ecology* 36: 103-115

Ukpong, I. E. (1995b) Vegetation and soil acidity of a mangrove swamp forest in South eastern Nigeria. *Soil Use and Management*, 11: 141-144.

Ukpong, I. E. (1997a) Vegetation and its relation to soil nutrient and salinity in the Calabar Mangrove swamp, Nigeria. *Mangroves and Salt Marshes* 1: 211-218

Ukpong, I. E. (1997b) Influence of Mangroves on the acidity and salinity characteristics of tidal soils. *Trans. Nig. Soc. Biol. Conserv.* 6: 20-25.

Ukpong, I. E. (1997c) Influence of mangrove species on some nutrient properties of tidal soils from the coast of Nigeria, West Africa. *Trans. Nig. Soc. Biol. Conserv.* 6: 29-35.

Ukpong, I. E. (1998) The Composition and distribution of species in relation to soil nutrient gradients in mangrove swamps in South Eastern Nigeria. *Tropical Ecology* 39: 55-67.

Ukpong, I. E. (2007) Mangrove forest under threat? An evaluation of the integrity of mangrove ecosystem functioning. The 17th Professorial Inaugural Lecture Delivered in the University of Uyo, Nigeria, 1st March, 2007.

Wilding, L. P. and L. R. Drees (1978) Spatial variability: a Pedologist's viewpoint, In: *Diversity of Soils in the Tropics.* A.S.A. Publ. 34: 1 -12.